United States Army School of Aviation Medicine
Fort Rucker, Alabama
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Student Handout

TITLE: Aviation Toxicology

FILE NUMBER: U3004508

PROPONENT FOR THIS LESSON PLAN IS:

United States Army School of Aviation Medicine
ATTN: MCCS-HAF
Fort Rucker, Alabama 36362-5377

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Aviation Toxicology
U3004508 / Version 1
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Prerequisite Lesson(s)	**Lesson Number** / **Lesson Title** None
Clearance Access	Security Level: Unclassified Requirements: There are no clearance or access requirements for the lesson.
Foreign Disclosure Restrictions	FD5. This product/publication has been reviewed by the product developers in coordination with the USASAM foreign disclosure authority. This product is releasable to students from all requesting foreign countries without restrictions.

References

Number	Title	Date	Additional Information
FM 3-04.301	Standards of Medical Fitness	29 SEP 2000	
	Fundamentals of Aerospace Medicine		

Student Study Assignments

Study student handout and review reference materials listed above.

Terminal Learning Objective

Action:	Prevent toxic substance exposure in the aviation environment.
Conditions:	While performing as an aircrew member.
Standards:	In accordance with (IAW) FM 3-04.301 and Fundamentals of Aerospace Medicine.

Safety Requirements	None.
Risk Assessment Level	Low - RISK ASSESSMENT LEVEL: Low.
Environmental Considerations	**NOTE:** It is the responsibility of all soldiers and DA civilians to protect the environment from damage. None.
Evaluation	On the last day of aviation medicine academics, each student will be evaluated on this block with a 50 question examination in which they must answer 35 of 50 questions correctly to receive a passing score. The test will be given in room X110 of Bldg 301.

A. ENABLING LEARNING OBJECTIVE

ACTION:	Determine the essential component of the Aviation Medicine Program.
CONDITIONS:	While serving as an aircrew member.
STANDARDS:	IAW FM 3-04.301, Fundamentals of Aerospace Medicine, Occupational Health In Aviation.

1. Learning Step / Activity 1. Provide instruction on historical toxic hazards.

a. History of Occupational Medicine in Aviation.

(1). Occupational Medicine an essential component of the Army Aviation Medicine Program. Its purpose is to prevent and solve problems involving potential toxic hazards in the aviation environment.

(2). The roots of occupational medicine can be traced back to Hippocrates (circ 400 B.C.) who first described not only the relationship between work and illnesses, but also discussed the principles of toxicology during research to control the absorption of a compound to prevent overdose.

(3). As long ago as the 16th century, people recognized that there is no such thing as an absolutely safe chemical. The Swiss physician Paracelsus, who lived from 1493 to 1541, said:

"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy."

(4) Bernardino Ramazzini's book "De Morbis Artificum", written in the early 18th century described numerous diseases caused by exposure to toxins in the work environment. Some of the descriptions of the occupational diseases were initially so well written that they have undergone very little revision over the past 200 years.

(5). Since the onset of powered flight in 1903, occupational medicine has attempted to keep pace with the cause and effect relationship between work and work-related illnesses. During WWI the first aircraft engines used a castor oil mix for lubrication. The relatively loose tolerances of early reciprocating engines allowed a continuous mist of castor oil to be sprayed into the air, whichsubsequently washed aft, over the pilot. To counteract the spray, the pilots wore long scarves to wipe the mist from their goggles. The ingested/inhaled mist caused frequent respiratory and gastrointestinal problems. Many of the substances used in aviation today are highly toxic to humans. The numbers of these substances are increasing as new materials are used to manufacture, operate, maintain, and repair aircraft.

(6). Currently more than one million people work in the aviation environment. Pilots, mechanics, ground crew, aircrew and other support personnel are continually exposed to toxicological hazards that are unique to their occupation. It is your duty as aviators and leaders in aviation to ensure you are familiar with the hazards of your workplace, and to take steps to mitigate the risk to your soldiers and yourselves.

B. ENABLING LEARNING OBJECTIVE

ACTION:	Identify an exposure.
CONDITIONS:	While serving as an aircrew member.
STANDARDS:	IAW FM 3-04.301, and Fundamentals of Aerospace Medicine.

1. Learning Step / Activity 1. Provide instruction on the toxic hazard terms and the definitions.

a. List of Terms and Definitions:

(1). Occupational Hazard - Anything capable of producing an adverse health effect (through either illness or injury) on a worker. It is imperative to identify and implement protections (substitution, re-engineering, personal protective measures) to minimize the potential hazards to workers.

(2). Toxicology: The scientific study of poisons. This can also be thought of as the study of physical and chemical agents and the injury caused to living cells.

(3). Exposure: The actual contact of the harmful substance with the biological organism.

(a). Acute Exposure: An exposure of an agent over a short period of time that can cause adverse health changes. May cause unrecognized decreased in perception and abilities/ skills. This is the greatest risk to aircrew members in flight. An example would be exposure to and inhalation of smoke in the cockpit due to fire.

(b). Chronic Exposure: A long-term exposure to an agent or a series of repeated exposures to an agent that may eventually lead to adverse health changes. Usually does not cause sudden incapacitation. May cause health changes many years later. Examples include cigarette smoking, asbestos exposure, and noise.

(4). Threshold Limit Values (TLV): It is economically unfeasible to rid the work environment entirely of hazardous materials, so the concept of threshold limit values was developed. TLV's represent the airborne limits of permitted concentrations of hazardous chemicals under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. These limits are subject to periodic revision and vary between different countries. The term *threshold limit* relates primarily to the USA, but equivalent terms are available in most industrialized countries. These values are timed weight concentrations of chemicals that will produce no apparent effect to an individual who are routinely exposed for eight hours a day.

(a). Short Term Exposure Limits (TLV-STEL): The Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) are time-weighted average concentrations of specific chemicals that are allowed for only 15 minutes during the workday. The TLV-STEL should not be exceeded at any time during a working day, even if the 8-hour time-weighted average is within the TLV. It is designed to protect workers from chemicals which may cause irritancy, chronic or irreversible tissue damage, or narcosis (change in mental status) which may increase the likelihood of accidental injury.

(b). Ceiling Concentration (TLV-C): For Threshold Limit Ceiling Values (TLV-C) the concentration should not be exceeded during any part of the working day.

C. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the aviation toxicology principles.
CONDITIONS:	While serving as an aircrew member.
STANDARDS:	IAW FM 3-04.301 and Fundamentals of Aerospace Medicine.

1. Learning Step / Activity 1. Provide instruction on list of factors and their definitions.

a. Aviation Toxicology Principles:

(1). Time and Dose Principle: The effects of a toxin on the body depend on the duration and route of exposure. As the concentration of a toxin increases the period of time between exposure and onset of symptoms decreases.

(2). Route of Entry Principle: There are three principle ways a toxin can enter the body.

(a). Inhalation: In the flight environment this is the most important method. The surface area of the lung is enormous. When inhaled, most toxins are absorbed directly into the blood stream due to the extremely short distance the gas must move from the lungs to the blood.

NOTE: The blood in the alveolar capillaries is separated from alveolar air by 3 cell layers totaling 6 thousandths of a mm.

(b). Absorption: This involves movement of the toxin through the skin. Many organic solvents permeate the skin easily while the majority of inorganic substances and dust do not. The absorption of airborne gases through the skin is also poor.

(c). Ingestion: Involves taking substance in through the mouth accidentally. Smoking, eating, or drinking in work areas without adequate precautions are the main means of exposure through ingestion.

(3). Rate of Retention and Excretion Principles:

(a). Retention: How long the toxin is kept within the body. Toxins' with high retention rates are: Lead, DDT, Asbestos, Beryllium.

(b). Excretion: How quickly the body rids itself of the toxin. This is usually through the liver or kidneys. Water-soluble toxins are typically excreted more quickly than fat-soluble toxins.

(4). Physiological Principles: Individual variability principles that determine the response to a toxin.

(a). Metabolism slows with age. Dosing medications and being exposed to toxins becomes more critical. It should be intuitive that those individuals with slower metabolic rates will take longer to excrete toxins than would those with faster rates.

(b). The amount of body fat determines the effect of fat-soluble toxins. The more body fat a person has, the more fat-soluble toxin that is absorbed and the longer it takes the body to excrete it.

(c). Genetics affect how your body will respond to some toxins. Examples include G6PD deficiency (this defect results in the hemolysis {breaking} of red blood cells when the individual is exposed to certain toxins such as ozone or oxides of nitrogen), sickle cell anemia (this defect of the red blood cell can pose a potential risk when exposed to carbon monoxide or cyanide) and other inherited metabolic disorders.

(5). Physiochemical Principles: The biochemical processes of detoxifying chemicals within the body. The body begins to break down any substance into its basic components in an attempt to obtain nutrition or detoxify the body. The liver and kidneys are the principle organs involved in this process.

(6). Environmental Principals: Toxicity may be affected by atmospheric pressure, temperature, and humidity.

(a). Atmospheric pressure: FAA studies show that hazardous fumes/vapors become more toxic the higher you go in altitude. (e.g. carbon monoxide at ground level may have little or no effect but as you gain altitude the same amount may cause impairment, as the hypoxia of altitude is exacerbated by CO.

(b). Temperature: Some toxic agents are less problematic in winter than in summer due to larger vaporization of volatile chemicals in warmer temperature. However, cold weather can cause dry, cracked skin, which can facilitate absorption of chemicals through the dermal layers.

(c). Humidity: Chemicals are more rapidly absorbed through wet (perspiration) skin than dry cool skin.

D. ENABLING LEARNING OBJECTIVE

ACTION:	Identify aviation toxic substances.
CONDITIONS:	While serving as an aircrew member.
STANDARDS:	IAW FM 3-04.301, AR 50-5, and AR 50-6.

1. Learning Step / Activity 1. Provide instruction on aviation toxic substances and their reactions.

a. Toxic Substance Overview: As an aircrew member, you will be exposed to various contaminants in the aviation environment. Your exposure will vary depending on your duties and personal meticulousness, but no one involved in aviation will be able to completely avoid exposure.

b. Aviation Fuels:

(1). Military aircraft use Jet Propulsion (JP) series of fuels (JP4, 5, and 8) and can use AVGAS as an alternate emergency fuel source.

(2). Jet Propulsion Fuels are various mixtures of hydrocarbons producing different grades of kerosene. Each JP fuel has its own flash and vapor point. JP 8 is nearly 100% kerosene and has a higher flash point and lower vapor pressure point.

(3). Aviation gasoline (AVGAS) is a mixture of hydrocarbons and additives of which tetraethyl lead is used as an additive. Tetraethyl lead is extremely toxic to the nervous system due to the lead content. Other additives include known carcinogens Toluene, Xylene, and Benzene.

(4). The principle hazard for JP fuels is vapor inhalation. Its low volatility and higher flash points cause engine choking and cold starts. This combination often exposes soldiers to unburned aerosolized fuel. The low volatility also causes the fuel to remain on the clothes and skin for a longer period of time.

(5). The signs and symptoms of toxic fuel exposure are lightheadedness, confusion, fatigue, coma, slurred speech, and impaired psychomotor skills. Irregular heartbeats, coughing, choking wheezing, nausea, vomiting, and chemical burns can also occur.

(6). Chronic high exposure can lead to leukemia,. brain and peripheral nerve damage.

NOTE: Not usually a problem unless an individual works around fuel cells routinely.

c. Aviation Fuel Combustion:

(1). Carbon Monoxide: It is one of the most common and toxic of substances in the aviation environment. It's an odorless, tasteless, and colorless vapor. Negligible amounts are produced with aircraft turbine engines. Whenever exhaust fumes are noted carbon monoxide should be expected. Relatively low concentrations in the air can, over time, produce high blood concentrations. Inhaling as little as 0.5% in the breathing atmosphere for 30 minutes at rest will produce a blood concentration of 45%. With as little as 10% concentration of carbon monoxide in the blood, peripheral vision and night visual acuity are decreased.

(2). The effects of carbon monoxide intoxication include: headache, weakness, dizziness, nausea, confusion, and loss of consciousness. The classic cherry red coloration of nail beds and lips does not occur until the concentration of CO is greater than 40%.

d. Solvents/Degreasers: Organic bases used to dissolve other petroleum products. Water based solvents: Alcohol (Isopropanol, Ethylene glycol, De-Icing fluids); Ketones-[Acetone, Methyl-ethyl-ketone (MEK)]; Esters-(Ethyl acetate). Alcohol based solvents: Aromatic hydrocarbons (Benzene, Tolulene); Aliphatic hydrocarbons (*n*-Hexane); Chlorinated hydrocarbons (Chloroform, TCE, TCA)

(1). Toluene Isocyante: Present as an additive to paints, foams, and adhesive. Causes redness and blistering of the eyes, nose, and respiratory tract. Can cause central nervous system wasting.

(2). Trichloroethylene (TCE): A halogenated hydrocarbon fluid, which has a sweet odor, commonly used in aircraft maintenance as solvents or degreasing agents. The most common side effects have been those on the central nervous system. The fumes are readily absorbed from the lungs and predominately cause headache dizziness, vertigo, tremor, nausea, vomiting and fatigue (symptoms similar to alcohol intoxication)in large exposures it can cause coma and death.

(3). Methyl-ethyl-ketone (MEK): Cleaning solvent specified by the maintenance manual. MEK is not very toxic, unless exposed to high concentrations for long periods of time. With skin contact it can cause skin dermatitis with drying, fissuring, and scaling. The potential hazard is inhalation of fumes. It is irritating to the mucous membranes, can cause headache, dizziness, nausea, vomiting, loss of coordination and central nervous system (CNS) depression.

e. Lubricants: Substances that reduce friction. Lubricating oils used in aircraft are located throughout the airframe (Engine, APU, Transmissions, and Gear boxes). When the oil escapes on to hot surfaces an inhalation hazard is produced. Inhalation of these fumes can cause symptoms similar to carbon monoxide poisoning. When in prolonged contact with the skin it may cause a dermatitis type of reaction. If aerosolized the mist could cause respiratory irritation.

f. Hydraulic Fluids: Hydraulic fluids are either Petroleum, Castor oil, silicon, or phosphate based. The fluids are maintained under high pressure. A leak from a hose or gauge under pressure can produce a finely aerosolized mist that can diffuse throughout the cockpit. Large leaks can cause pooling of hydraulic fluid in the cockpit. Fine mist may impair vision and act as an irritant to the eyes. Inhalation of the mist can irritate the lungs.

g. Fire Extinguisher: Fire extinguishers can pose a threat to the aircrew when operated in either an enclosed environment or airy environment. Inhalation of these agents is the primary threat. There are three types of fire extinguishing agents in use.

(1). Halon (Halogenated Hydrocarbon): Is a liquefied compressed gas, which stops the spread of fire by chemically interrupting combustion. Halon is colorless, odorless, nonconductive, and does not leave a chemical residue. It is relatively nontoxic except when discharged in an enclosed space. In an enclosed space it acts as an asphyxiant (displaces oxygen). Under extremely high temperature this gas can decompose into other more toxic gases (hydrogen fluoride, hydrogen chloride, hydrogen bromide, and phosgene.

(2). Carbon Dioxide: Safe fire extinguisher, although large quantities are often required to extinguish fires. Because it is heavier than air it accumulates in lower areas, especially in enclosed spaces. In low concentrations, less than two percent, carbon dioxide acts as a respiratory stimulant. In higher concentrations (2-5%) drowsiness, headache, respiratory difficulty, lack of coordination can occur. In concentrations of 10% and above collapse, loss of consciousness and death can occur.

(3). Aqueous Film Forming Foam (AFFF): A protein based product that is relatively nontoxic. Almost_ exclusively found around flight lines. The concentrated foam is a harsh detergent, which can irritate the skin.

h. Composites and Plastics

(1). Composite Materials: Composed of a number of components, which give it added strength, lighter weight, and thermal resistance. Made up of resins, strengthening fibers, and solvents.

(2). Fibers: Include carbon graphite, boron fibers, kevlar and fiberglass. Problems occur during crash, reworking, burning, sanding, or scraping. The hazard is primarily inhalation of particles of less than 3.5 micrometers. Inhalation of large amounts can lead to development of an asbestosis like reaction..

(3). Resins: Bonding agents, which provide insulation and the physical resistant properties of composites. Resins used are epoxy, polyurethane, phenol and amino resins. The primary hazard is inhalation. Thermal decomposition may release toluene diisocyantes or methylene dianiline(MDA) fumes. CNS depression, unconsciousness, allergic asthma, and allergic skin reactions may occur.

(4). Plastics: Polyurethane used in cockpit/cabin interiors and fluorocarbon plastics used as wiring insulation and corrosion resistant coating. Primary hazard is inhalation during thermal decomposition, which may release chemicals such as cyanide, fluorine gas, and phosgene.

E. ENABLING LEARNING OBJECTIVE

ACTION:	Identify protective measures to prevent or reduce toxic substance exposure.
CONDITIONS:	While serving as an aircrew member.
STANDARDS:	IAW FM 1-304.301, AR 50-5, and AR 50-6.

1. Learning Step / Activity 1. Provide instruction on protective measures to prevent or reduce toxic substance exposure.

a. Protective Measures:

(1). Individual: Prevent contamination of your flight suit. When contaminated it is just as flammable as the contaminant. Smoke and eat only in authorized areas, and wash hands prior to eating and smoking to mitigate the threat of ingesting a toxin. Wear personal protective equipment while working in areas that may expose you to inhalation, absorption, or ingestion of toxic agents. Periodically analyze your own processes, pay strict attention to any physical symptoms, which may indicate exposure to a toxin.

(2). Cockpit: Be acutely aware of the potential for exposure to toxins in flight. Smoke and fumes are a very serious matter and crew may not be aware of what the source is. Remember your immediate action measures, such as rapid ventilation of the cockpit, descending from high altitude, landing, and evacuating the aircraft as soon as possible. Get medical evaluation for possible toxic exposure.

(3). General: Be acutely aware of the potential for toxin exposures in the aviation environment and the lethality of them in flight. Always work in well-ventilated areas when working with toxic substances. Be aware of the hazardous materials in the work area. Develop and, rehearse evacuation plans.